LUNAR DIELECTRIC CONSTANTS FROM APERTURE SYNTHESIS POLARIMETRY AT 6 CM. J.L. Margot, D.B. Campbell, *Department of Astronomy and Space Sciences, Cornell University, Ithaca, NY 14853*, B.A. Campbell, *Center for Earth & Planetary Studies, National Air & Space Museum, Washington, DC 20560*, B.J. Butler, *National Radio Astronomy Observatory, P.O. Box 0, Socorro, NM 87801*.

Measurements of the Moon's polarized thermal radio emission at 6 cm were obtained with the Very Large Array (VLA). The polarization properties of the emission are determined primarily by the dielectric constant of the regolith material, the fraction of the emergent radiation that is diffused, and the surface roughness on scales larger than the wavelength. Maps of all Stokes parameters were used to provide estimates of the regolith dielectric constant at ∼25 km resolution. The values for a smooth Moon range from ∼1.6 to ∼2.5, with an average of ∼2.0. These values are lower than those derived from similar emission measurements at 21 cm [1] ($\epsilon \simeq 2.7$) and from earlier radar estimates ($\epsilon \geq 2.5$). Results are illustrated for the Crisium and Sinus Iridum areas where some mare regions have dielectric constants ∼2.1 and highland regions have values of ∼1.9. These variations cannot be accounted for by large scale roughness alone.

The observations were performed with the VLA[1] in its most compact (D) configuration on April 12, 1995. Eight hours of observation were used to cycle through four different sites. The array resolution at the center of the lunar disk was 14'', or 25 km, and the diameter of each area imaged was 8', or roughly 1000 km. Stokes parameters were formed by combining measurements in two circular polarizations.

Because the interferometer did not sample critical low spatial frequency components, traditional deconvolution algorithms failed to properly remove the array sidelobe response and to improve image quality. Image restoration was achieved by fitting models of the emission in each Stokes parameter to the visibility function, thereby providing the low spatial frequency components unseen by the interferometer. These model components were then combined with the high resolution data to form images.

Deconvolved images of the Stokes parameters were used to compute the degree of linear polarization of the Lunar thermal emission, which in turn provides estimates of the dielectric constant. The inversion method was outlined in Margot et al. [1] and relies on differences between the transmission coefficients parallel and perpendicular to the plane of emission at the regolith-vacuum interface. This technique is independent of absolute calibration and is limited to high emission angles. It is fairly insensitive to the loss tangent of the material, and therefore more diagnostic of bulk density than oxide content.

Results of the fits for the four areas observed are illustrated in table 1, and variations at each site are roughly ±0.2 about the indicated average value. (The fits at the last site yield a temperature value higher than expected which, if in error, would result in a slight underestimate of ϵ). Dielectric constant

Site	Lat	Lon	ϵ_{avg}
S. Iridum	39.5	-32.5	2.1
Tycho	-47.0	-11.3	2.0
Plato	55.0	-9.7	2.2
Crisium	17.4	29.0	1.9

Table 1: Average dielectric constants obtained at the observed sites by fitting the visibility function.

values centered around 2.0 are in agreement with previous radio polarimetric studies at 6 cm [2], but contrast with typical radar estimates of the dielectric constant (≥ 2.5) at comparable wavelengths [3][4]. Diffusion by wavelength-scale structure at the surface lowers radio estimates of the dielectric constants and partially explains the discrepancy.

The observed values of the dielectric constant at 6 cm also contrast with an average value of 2.7 obtained at 21 cm using the same technique [1]. In an attempt to explain the discrepancy, radiative transfer modeling was performed on various density profiles of the upper regolith. These simulations showed that the measured values of the dielectric constant are characteristic of the very top layer of the regolith (depth $\lambda/10$ or less), unless sharp density increases are present. No realistic density profile of the upper meter of the regolith could reproduce both values inferred at wavelengths of 6 cm and 21 cm, even when very abrupt density profiles were considered. A layer of bedrock with higher dielectric constant ($\epsilon = 6.5$) better explains the observed values at the two wavelengths, but only if placed very close to the surface (∼1 meter).

Maps of the dielectric constant around Crisium and Sinus Iridum are shown in figures 1 (a) and 2 (a) respectively. Arecibo 70 cm radar backscatter maps [5] of the same regions are provided for comparison. As observed previously at 21 cm [1], some mare units display higher dielectric constants than the surrounding highlands, and the difference cannot be accounted for by large scale roughness effects alone. Typical variations at Sinus Iridum are 1.9 to 2.3 at 6 cm, while the values measured at 21 cm ranged from 2.4 to 3.0. If interpreted in terms of bulk density at the regolith interface, the highland and mare regions would have a density of ∼1.0 gcm^{-3} and 1.2 gcm^{-3} respectively, in contrast with higher estimates at 21 cm wavelength [1].

[1] The VLA is a facility of the National Radio Astronomy Observatory which is operated by Associated Universities, Inc., under cooperative agreement with the National Science Foundation.

References

[1] J. L. Margot, D. B. Campbell, B. A. Campbell, and B. J. Butler. Lunar dielectric constants from radio thermal emission

measurements. *Lunar and Planetary Science Conference XXVII*, pages 805--806, Mar 1996.

[2] R. D. Davies and F. F. Gardner. Linear polarization of the Moon at 6, 11 and 21 cm wavelengths. *Aust. J. Phys.*, 19:823--836, 1966.

[3] Tor Hagfors. Microwave studies of thermal emission from the Moon. In *Advances in Astronomy and Astrophysics*, volume 8. Academic Press, New-York, 1971.

[4] Nicholas John Sholto Stacy. *High-resolution synthetic aperture radar observations of the Moon*. PhD thesis, Cornell University, 1993.

[5] T. W. Thompson. High-resolution lunar radar map at 70-cm wavelength. *Earth, Moon, Planets*, 37:59--70, 1987.

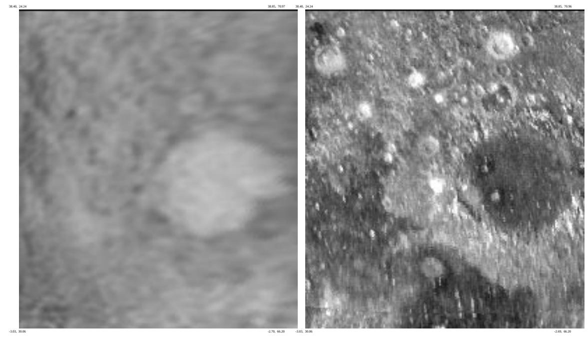

Figure 1: (a) Dielectric constant map of the Mare Crisium area obtained from thermal emission measurements at 6 cm. Values range from 1.8 to 2.1. The map includes selenographic latitudes from -3° to 40°, and longitudes from 24° to 70° East. (b) Arecibo radar map of the same region at 70 cm.

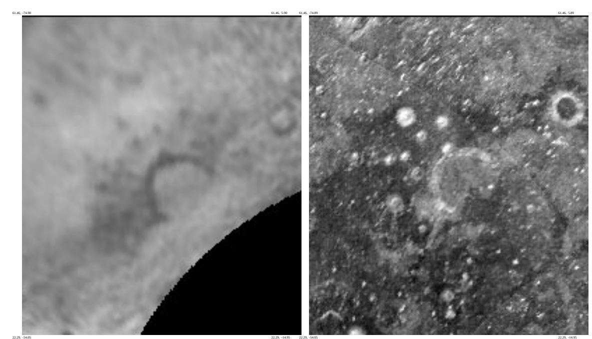

Figure 2: (a) Dielectric constant map of the Sinus Iridum area obtained from thermal emission measurements at 6 cm. Values range from 1.9 to 2.3. The map includes selenographic latitudes from 23° to 63°, and longitudes from 0° to 72° West. The blanked region corresponds to emission angles lower than 35°, where the inversion is unreliable. (b) Arecibo radar map of the same region at 70 cm.